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OBSERVATIONS ON THE BIOLOGY OF SOME COPROPHAGOUS BORBORIDAE (DIPTERA).

By M. Hafez, M.Sc., Ph.D., F.R.E.S.

(*Department of Entomology, Faculty of Science, Fouad I University, Cairo*).

In a previous account of the insect fauna of dung in Egypt (Hafez, 1939) the present author recorded two coprophagous species of Borboridae and described the life-history of one of them, *Leptocera digitata* Duda. Since then five more species have been recorded (Hafez, 1947), and further observations on their biology have been made in three localities in the region of Cairo in 1940–1942. The results obtained are given in the present paper, which was completed and prepared for publication at the Zoological Laboratory, University of Cambridge.

The literature contains little work on the biology of the dung-haunting species of Borboridae. Valuable information on the biology of several species is, however, included in the works of Richards (1930) and Hammer (1941). Brief biological notes have also been given by Howard (1900), Dahl (1909), Wahlgren (1918), Duda (1920) and Séguy (1934), etc.

The following coprophagous species of Borboridae are known to occur in Egypt:

Leptocera (= *Limosina*) *curvinervis* Stenhammar (= *roralis* Rondani).
Leptocera vagans var. *rufa* Duda.
Leptocera fuscipennis Haliday.
Leptocera puerula Rondani.
Leptocera (*Elachisoma*) *nigerrima* Haliday.
Leptocera digitata Duda.
Leptocera ferruginata Stenhammar.

Breeding Media.

These flies are the most numerous of all dung insects. They appear in great abundance on fresh and old dung. On large manure heaps they are commonly seen in huge swarms.

Judging by field observations and laboratory breeding experiments, some of these flies breed mainly in one particular kind of dung, while some others do not show this tendency. For instance, horse manure seems to attract the ovipositing females of *L. digitata*, *L. ferruginata*, *L. vagans* var. *rufa* and *L. puerula* more than any other kind of dung. Sheep dung comes next to horse manure in its power of attraction to these flies, whereas cow and buffalo dung are very inferior in this respect. On many occasions where the flies were offered horse and cow dung, the latter was avoided by the ovipositing females. On the other hand, *L. curvinervis*, *L. fuscipennis* and *L. nigerrima* emerged from all kinds of dung in relatively large numbers, and the latter species seems to prefer cow dung for oviposition. Table I shows typical results of five breeding experiments in four species.

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TABLE I.—*Total Number of Flies Emerging in Five Experiments from Different Kinds of Dung Exposed to Ovipositing Females for Two Hours (from* 10 *a.m. to* 12 *noon) in the Open in May,* 1941. *In Each Experiment Six Equal Masses (each a pound in weight and* 400 *sq. cm. in surface area) of Fresh Cow, Buffalo, Horse, Sheep, Pig and Camel Dung were Used. Temperature during all Experiments was* 26–28° C.

Species.	Number of flies emerged from the dung of—					
	Horse.	Sheep.	Buffalo.	Cow.	Camel.	Pig.
L. digitata	6120	3814	38	51	5231	11
L. ferruginata	7008	4270	13	68	4138	7
L. fuscipennis	1839	917	872	1130	530	430
L. nigerrima	2025	717	2930	1813	952	763

The tendency in the different species to prefer the dung of particular species of animals has been observed by previous workers. For instance, Hammer (1941) pointed out that very few *Coprophila* (*Leptocera*) *pusilla* and *L. ferruginata* are found on cow dung, while they occur in thousands on horse-droppings. Also Richards (1930) recorded the abundant occurrence of *L. crassimana* on horse manure and its absence or rare occurrence on cow dung. Thomsen and Hammer (1936) have similarly shown that the greatest numbers of *Leptocera* sp. (*Limosina*) emerged from horse-manure, while cow dung yielded only a few individuals.

SEASONAL PREVALENCE.

These flies are commonly seen on dung in nearly all months of the year, *L. digitata* and *L. ferruginata* being more abundant than the other species. During the spring (April and May) and the autumn (mainly September), the breeding activity of these two species attains its height and they usually occur in huge swarms, especially on large manure heaps and in stables. On the coldest days of January and February, when the atmospheric temperature falls below 10° C. the number of flies visiting the dung is greatly diminished. On the other hand, *L. vagans* and *L. nigerrima* seem to be little affected by the seasons. They appear to be equally abundant all the year round. These observations are in agreement with the results obtained from laboratory breeding experiments (fig. 1).

APPEARANCE ON THE DUNG.

These flies are generally the first insects to appear on fresh horse dung. They may appear on the droppings one or two minutes after defaecation. They first occur in small numbers, but these steadily increase to several hundreds in a few hours. For instance, in *L. ferruginata* as many as 1000 flies could be collected on a six-hours-old dropping (about two pounds in weight and 400 sq. cm. in surface area). Twice this number of flies occurred on the dung at the end of twenty-four hours, and was nearly maintained over a period of another twenty-four hours. After that a gradual fall took place, and by the seventh day practically no flies were seen on or in the dung. In large manure heaps the flies may occur in great numbers on much older dung. For instance *L. ferruginata* and *L. nigerrima* were often found on dung about twenty days old.

These flies are not confined to the surface of the dung mass, but also occur inside and below it, especially during the winter, when they become very sluggish in movement. In these concealed situations ventilation is made possible through the numerous tunnels made by the Scarabaeid beetles. This tendency to occur inside the dung mass may be due to a preference for higher humidity. According to Hammer (1941), these insects are very sensitive to low humidities, and some of them (e.g. *Elachisoma nigerrima*) die in less than 90 minutes at ordinary air temperature and air humidity.

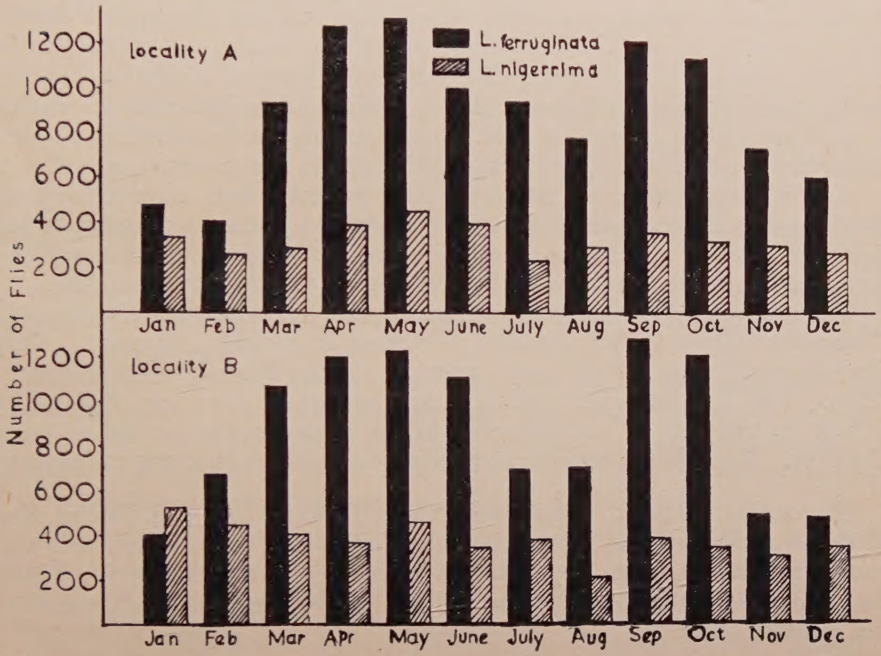

FIG. 1.—Number of flies emerging from equal masses (each one pound in weight and 400 sq. cm. in surface area) of fresh horse dung after six hours exposure (from 10 a.m. to 4 p.m.) in the open to ovipositing females in two localities, A and B. The results are the average of ten experiments repeated in every month in 1941. Temperature during all experiments was 25–28°C.

LIFE-HISTORY—GENERAL.

The eggs are laid in fresh and old dung; the former, however, attracts the ovipositing females in greater numbers. During oviposition the egg is forced into the dung, with its anterior end, which carries two respiratory appendages, projecting towards the surface. More eggs seem to be laid inside the dung mass than on the surface. In *L. ferruginata* the egg is about 0·4 mm. in length and 0·18 mm. in breadth, white in colour and provided with a pair of long, slightly curved respiratory appendages. The egg hatches in about eight hours at 28° C.

The larva feeds on the dung, but the actual substances on which it feeds are not definitely known. It is very probable that such coprophagous larvae feed on the micro-organisms which are abundant in the dung (Baumberger, 1919, and Hammer, 1941). The larval stage lasts in all species from 3 to 4 days at 28° C.

Prior to pupation the larvae seem to burrow downwards in the dung mass and collect below it on the surface of the ground. In this situation pupae are abundant. The duration of the pupal stage is about two days at 28° C.

PREDATORS.

The eggs and larvae of these flies are preyed upon by several dung predators, such as Histerid beetles (e.g. *Hister bimaculatus* L.) and Staphylinid beetles (e.g. *Philonthus quisquiliarius* Gyllenhall). These beetles are predaceous in both the adult and larval stages. Their mode of attack on the fly larvae is the same as that described in Sepsids (Hafez, 1948). An incision near the middle of the body of the fly larva is made by the sharply curved mandibles of the beetle larva and then the juice of the victim's body is apparently sucked.

As *Philonthus* beetles and larvae are more numerous and active in the dung than those of *Hister*, it seems that the former play a greater part in keeping down the numbers of flies emerging from the dung by attacking their eggs and larvae, although the individual devouring capacity of the latter is higher.

With the adult flies are associated three species of Empid flies (*Drapetis* sp.; *Cossopalpus aenescens* Wiedemann; *Tachydromia pictitarsis* Becker). Very likely these Empids are predatory associates of the Borborid flies (Richards, 1930). Also in most species of *Leptocera* examined there appeared nearly always one red mite or more attached to the ventral surface of the abdomen of the fly. The relation between these mites and the fly is not well understood.

The author wishes to express his sincere thanks to H. C. Efflatoun Bey, Professor of Entomology, Fouad I University, Cairo, for his kind help and encouragement, to Capt. J. L. Cloudsley-Thompson for checking the proofs, etc., and to Dr. John Smart, Zoological Laboratory, University of Cambridge, for valuable criticism.

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Book Notices.

Bee Keeping in Britain. By R. O. B. Manley. 8vo. London : Faber & Faber, 1948. Pp. 439. 28 pls. Price 21s.

This work covers the whole field of bee-keeping and is the product of the author's lifetime experience. It contains information of value both to the beginner and the expert.

The life of the honey bee is dealt with very fully at the beginning, and succeeding chapters deal with the practical aspects of bee-keeping and the problems the novice is likely to encounter. Modern commercial methods and equipment are discussed and the final chapter outlines the prospects in front of those thinking of taking up bee-keeping under present conditions.

Butterfly Haunts. By L. Hugh Newman. 8vo. London : Chapman & Hall, 1948. Pp. viii + 132. 128 ~~pls.~~ Price £1 1s.

This book consists of close-up photographs of every British butterfly, including the migrants, with their foodplant. A few lines of explanatory text are given beneath each species, and on the facing right-hand page are one or more excellent photographs of the type of country in which the insect is to be found.

NOTES ON FOUR INDIAN BOMBYCID SPECIES.

By D. G. Sevastopulo, F.R.E.S.

Ocinara varians Walker.

This common species usually feeds on Pipul (*Ficus religiosa*), but in December, 1941, in Calcutta, I found a number of half-grown larvae on *Streblus asper*, belonging to the same order (Moraceae). These larvae were normal, but when passing the place some few days later I noticed that they had moulted into the final instar and that they were then rather different from the usual form, being smaller, darker and more knobbed. Pipul is not unlike Black Poplar, both in regard to the shape and texture of its leaves and their arrangement on the twig, whilst *S. asper* is more like an elm, with small dry leaves and rough twigs. If the two forms of larvae belong to the same species, the difference in appearance is, presumably, due to the difference in environment. The imagines I obtained were all males, all of a peculiar silver-grey, which I have not been able to match exactly in my series. I have always intended to rear a brood from ova in part on Pipul and in part on *Streblus asper* and see if this larval difference re-appears, but up to now I have not done so.

Prismosticta fenestrata Butler.

This species was described as a Bombycid, but both Hampson in the *Fauna of British India* (Moths 1), and Strand in Seitz' *Indo-Australian Bombyces*, treat it as a Eupterotid belonging to the genus *Apha* Moore. The larva shows that it is a true Bombycid. The caudal horn of the larva is soft, not hard as in the Sphingidae, and can be curled downwards and straightened.

Andraca bipunctata Walker.

In a footnote in Seitz' *Indo-Australian Bombyces*, Gaede suggests that this species is really a Notodontid on account of its larval affinities. This is not unlike the larva of *Phalera bucephala* L. in colour, but Mr. Gardner, the Indian Forest Entomologist, has pointed out to me that the crochets of the prolegs are typical of the Bombycidae. The larva rests rather in the attitude of a *Stauropus*, gripping with the abdominal prolegs and with the fore- and hind-parts of the body raised and turned back over the dorsum. They are gregarious, so that a batch of them on a twig presents a very strange, tangled appearance. The resting attitude of the imago is typically Bombycid. I found that pupae from parasitised larvae of *Andraca bipunctata* showed vestiges of the abdominal prolegs. The pupa is small compared with the larva, and the parasite (a fairly large Dipteron, which unfortunately failed to emerge), presumably takes up so much space in the shrunken pre-pupa that it leaves no room for the withdrawal of the protoplasm of the prolegs into the body, and they therefore persist in the pupal stage.

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Mustillia falcipennis Walker.

Here again the larva is disproportionately large in comparison with the imago, but attention should be drawn to the protrusible organs on the underside of the 3rd thoracic segment. When the larva is disturbed the fore part of the body is retracted, expanding the lateral flaps, and these organs protrude like stalked eyes. The blown larva does not, unfortunately, give a proper idea of the larva either at rest or when disturbed, as the process of blowing extends the first two segments of the thorax, the lateral flaps, and also the stalked eye-like spots. When at rest naturally the fore part of the body is extended, but the lateral flaps and the eye-like spots are not expanded ; when disturbed the head and first two thoracic somites are withdrawn into the third and the lateral flaps and eye-like spots expanded, at the same time the caudal horn is curled and uncurled.

Book Notices.

Our Enemy the Termite. (Revised.) By T. E. Snyder. 8vo. Ithaca, N.Y. (Comstock Publishing Co.) and London (Constable), 1948. Pp. xiv + 257. 84 figs. Price 20s.

The first edition of this work appeared in 1935 and the progress in knowledge in the intervening years has necessitated a complete re-writing of certain sections of the book, and a revision of other portions.

The subject is dealt with under the following chapter headings : (1) Termites : what they are. (2) Metamorphosis and description of the castes. (3) The colonizing flight. (4) Nests. (5) The food of termites. (6) Guests or inquilines in termite nests. (7) The disturbance of the balance of nature by man. (8) Damage by termites. (9) Biological control of termites. (10) Methods and tests. (11) Artificial control of termites.

In this new edition keys to the genera or major groups of termites based on both structural characteristics and habits have been added. A glossary and index complete the book.

THE RELATION BETWEEN MEASUREMENTS OF THE SUCCESSIVE INSTARS OF INSECTS.

By O. W. Richards, M.A., D.Sc.

Dyar (1890) seems to have been the first to point out that there is some relation between the head-widths of successive instars of Lepidopterous larvae. According to him the successive measurements form a geometrical progression, bearing a constant ratio to one another. Although it is now known that the progression is rarely regular, it is usually sufficiently nearly so to serve Dyar's original purpose, which was to discover whether an instar had been overlooked.

Later authors (see discussion in Duarte, 1939 : 431) have attempted to elaborate Dyar's rule. In particular, Przibram has suggested that the number of body-cells is normally doubled at each moult. Exceptions to this principle have been explained by Bodenheimer as being due to so-called "latent" divisions. By postulating the correct number of these, almost any departure from the regular progression can be accounted for.

In studying the instars of some grasshoppers reared by Dr. N. Waloff and myself, it was noticed that there was regular relation between the measurements of the instars if account was taken of their varying durations. In other words, growth proceeds at a regular rate, and the longer the instar the greater the amount of growth; Dyar's rule only holds when the instars are all of the same length. These facts may be illustrated from a few miscellaneous records which were conveniently available, but the principle is probably widely applicable.

1. *Chorthippus parallelus* (Zetterstedt), ♀ (Acrididae).
(unpublished data, Richards and Waloff.)

Stage.	I.	II.	III.	IV.	Adult.
Mean hind femur length (mm.)	2·38	3·84	5·51	7·58	11·00
Duration of stage (days) . .	?	8·8	12·3	14·2	—
Accumulated days . . .	—	0	8·8	21·1	35·3

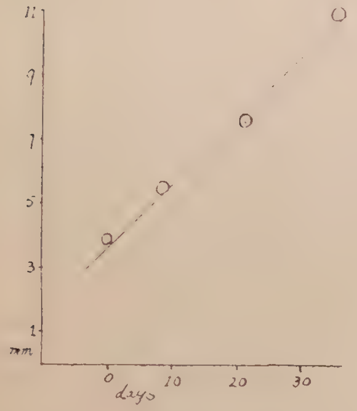
Regression of y (fem. length) on x (accumulated days): $y = 6{\cdot}89 + 0{\cdot}2\,(x - 16{\cdot}3)$. Calculated duration of Stage I, $y = 2{\cdot}38$, $x = 6{\cdot}7$ days. (Fig. 1.)

2. *Locusta migratoria migratorioides* (Reiche and Fairemaire), ♀ *solitaria* Duarte (1939).

Length hind femur and width head, Table II. Duration of instars, controls in Table XIII.

Stage.	I.	II.	III.	IV.	V.	Adult.
Mean femur length (mm.) . .	3·98	5·78	8·84	13·09	19·49	28·50
Mean head width (mm.) . .	1·44	1·98	2·86	3·96	5·51	6·61
Duration of stage (days) . .	4	5	3	6	7	—
Accumulated days . . .	0	4	9	12	18	25
Accumulated days (omitting Stage I)	—	0	5	8	14	21

Regression of femur length on time: (*a*) All stages, $y = 13 \cdot 28 + 1 \cdot 001\ (x - 11 \cdot 33)$; (*b*) omitting stage I, $y = 15 \cdot 14 + 1 \cdot 107\ (x - 9 \cdot 6)$. Regression of head width on time, $y = 3 \cdot 73 + 0 \cdot 224\ (x - 11 \cdot 33)$. (Fig. 2.)



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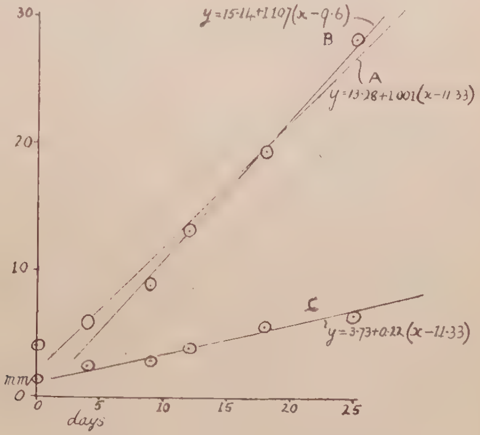

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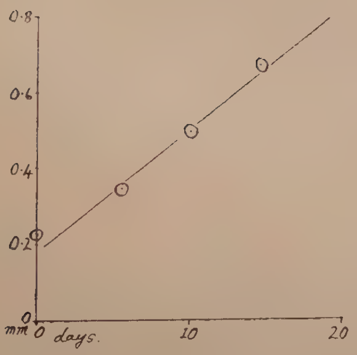
FIG. 1.—*Chorthippus parallelus*. Graph of mean length of hind femur against accumulated days.

FIG. 2.—*Locusta migratoria migratorioides*. Graph showing: A, relation of femur length to elapsed time, all stages; B, *ditto*, omitting stage 1; C, relation of head width to elapsed time.



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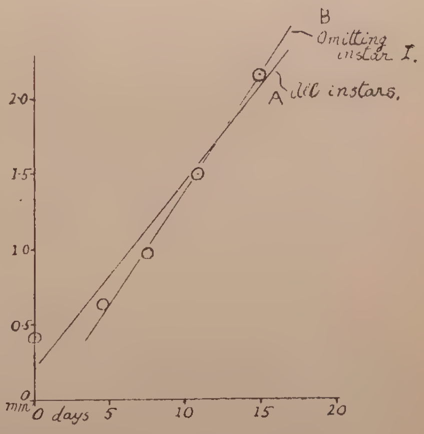

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FIG. 3.—*Calandra granaria*. Relation of head width to time.

FIG. 4.—*Pieris rapae*. A, Relation of head width to time; B, *ditto*, omitting first instar.

3. *Calandra granaria* (L.) (Col., CURCULIONIDAE), Richards (1947).

Stage.	I.	II.	III.	IV.
Mean larval head width (mm.) .	0·236	0·351	0·506	0·678
Duration of stage (days) . .	5·5	4·5	4·5	10
Accumulated days	0	5·5	10	14·5

Regression of head width on time: $y = \cdot 443 + 0\cdot 0306\,(x - 7\cdot 5)$. (Fig. 3.)

4. *Pieris rapae* (L.) (Lep. PIERIDAE), Richards (1940).

Stage.	I.	II.	III.	IV.	V.
Mean larval head width (mm.) .	0·42	0·64	0·97	1·50	2·26
Duration of stage (days) . .	4·5	3·0	3·3	4·1	7·8
Accumulated days . . .	0	4·5	7·5	10·8	14·9
„ „ (omitting stage I)	—	0	3·0	6·3	10·4

Regression of head width on time: (*a*) Including all stages, $y = 1\cdot 158 + 0\cdot 125\,(x - 7\cdot 54)$; (*b*) omitting stage I, $y = 1\cdot 34 + 0\cdot 157\,(x - 4\cdot 925)$. (Fig. 4.)

DISCUSSION.

1. The points for the various instars lie sufficiently near straight lines to make the supposition reasonable that the growth increment per day is constant.

2. The point corresponding to the first instar always lies above the line on which the other instars lie. This is because in all the examples the first instar is relatively too long. It might be suggested that in this instar there is an initial period in which no growth takes place. As a result, the line calculated when the first instar is omitted gives a better fit for the other instars. Further, the theoretical calculation of the length of the first instar in *Chorthippus parallelus* female will probably be found to be too short.

3. The points for the various instars lie sufficiently nearly on a straight line for the method to be useful in checking experimental results, particularly since linear measurements can often be made more accurately than estimates of the duration of instars.

4. In *Chorthippus* and *Locusta*, and in *Bombyx mori* L. (data for this species are given by Imms, 1934 : 196), it was found that the logarithms of the weights, or better the one-third powers of the weights, of successive instars lie on analogous straight lines.

5. Judging from *Chorthippus*, the relation between linear measurements and time is not affected by ordinary temperature fluctuations provided that each instar is subjected to the same mean temperature.

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RICHARDS, O. W., 1940, The biology of the Small White butterfly, etc. *J. anim. Ecol.* **9** : 243–288.

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A NOTE ON *PALOPHUS TIARATUS* ST. (ORTHOPTERA-PHASMIDAE) FROM SOUTHERN RHODESIA.

By N. C. E. Miller, F.R.E.S., F.Z.S., F.E.S.S.A.

A female of this large Phasmid was brought to me in the Odzi district on 20th July, 1947. It lived for a week and during that period deposited six ova singly, which it fixed by means of an adhesive substance to the walls of the glass container, and another ovum on the soil therein. Oviposition took place at night or during the early hours of the morning.

During the week in which this insect was under observation it was very sluggish and, indeed, moved very little even when handled. The weather at this time was exceptionally cold and severe frosts occurred on several days, conditions which, no doubt, contributed to its sluggish behaviour.

On dissecting the insect, I found twelve more ova, all of which were fully developed and coated with a whitish, viscid substance. There were a few more ova which were by no means in so advanced a stage of development, which confirms that in the Phasmidae one ovum only develops at a time.

The period during which oviposition occurs in the Phasmidae generally is usually protracted, and a large number of ova is produced, only a few, however, being laid each day, with intervals during which no oviposition takes place.

The ovum (fig. 1, A and B) measures 8·00 mm. at its greatest length, and is, in my opinion, small for a very large insect. *P. tiaratus* measures 347·00 mm., from the apex of the anterior legs to the apex of the posterior legs and has a body length of 180 mm.

In shape the ova resemble those of certain Reduviidae. They are cylindrical, feebly curved, oblique at the opercular end, rounded at the opposite end and flattened on one side. Just beyond the middle on the rounded side they have an irregular, subcircular carina with a low elevation in the area enclosed by it. The surface of the chorion is shagreened and has, except on the flattened side, which is smooth, irregular ridges and low, rounded elevations. The operculum is sub-circular with the upper surface strongly rugose and with a low, conical elevation sub-medially.

Eclosion took place between 20th and 22nd January, 1948, the incubation period being thus 146–148 days. After the nymph has left the ovum, the operculum remains attached to the chorion.

Description of the Nymph.

The nymph in the 1st instar (fig. 1, C), approximately one month after eclosion, measures 22·00 mm. Its general coloration is dull ochreous. Antennae blackish. Head with a large pale ochreous spot in front of inter-ocular spines, the apices of which are pale ochreous. Femora with irregular, wide, blackish annulations, the basal annulation the darkest. Tibiae with the apex and a wide median annulation blackish. Tarsi pale ochreous with the apical segments infumate. Coxae blackish. The head and body have abundant, irregularly disposed, short, erect, black and whitish spines. The legs also have abundant, short, sub-erect spines.

The host-plant or plants of this species are unknown to me. When eclosion took place I supplied leaves of several species of indigenous trees, including *Terminalia sericea* Burch., *Bauhinia* sp., *Pterocarpus sericeus* Benth., and *Swartzia madagascariensis* Desv.; leaves of the last-mentioned were accepted, but eaten very sparingly. All these trees are abundant in this district.

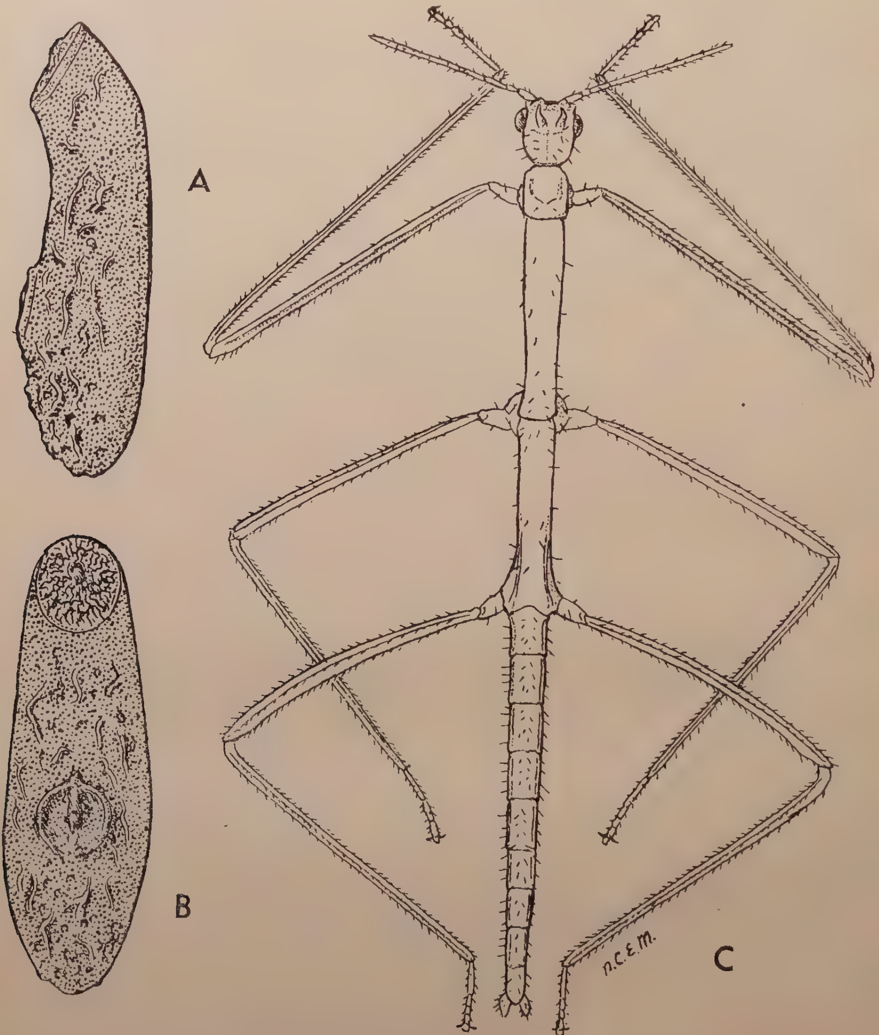

Fig. 1.—*Palophus tiaratus* St. A and B, ova; C, 1st instar nymph.

The male of P. *tiaratus* has been taken at light during the rainy season.

The method of oviposition in this species is of a type which is apparently uncommon in the PHASMIDAE, most of which, so far as records reveal, scatter their ova haphazard, and sometimes to a considerable distance, either in the vicinity of the host-plant or elsewhere.

A related species of *Palophus* (probably *episcopalis* Kirby), according to Burtt (1942, *Proc. R. ent. Soc. Lond.* (A) **17** : 75), also attaches its ova to some object or other by means of an adhesive substance.

Another method of oviposition has been recorded by the writer when in Malaya, the species in this case being *Heteropteryx dilatatus* (Parkinson). This Phasmid oviposited in the soil (Miller, 1939, *Proc. R. ent. Soc. Lond.* (A) **14** : 48).

It is interesting to note in this connection that Chopard (1938, *Biologie des Orthoptères*) states that while the habit of scattering the ova appears to be the most frequent with the PHASMIDAE, some genera, for example, *Leptynia*, insert their ova in a place in which they may be protected, such as in a fissure in the bark of a tree, where they are fixed by an adhesive either singly or in small, regular groups. This author refers also to two species, *Tachythorax maculicollis* and *Parasosibia parva* which, like the species referred to in the present paper, glue their ova to some object, and he suggests that this method of oviposition is probably not exceptional.

The writer wishes to thank his friend, Dr. B. P. Uvarov, for the identification of this Phasmid.

BOOK NOTICE.

The Songs of Insects, with Related Material on the Production, Detection and Measurement of Sonic and Supersonic Vibrations. By G. W. PIERCE, Ph.D. Pp. vii + 329. 1 col. pl. 243 figs. Harvard University Press (London : Geoffrey Cumberlege.) 1948. Price 27s. 6d.

This book presents the results of twelve years research by the author, a physicist, who has himself invented apparatus and devised methods for investigating the sounds made by insects.

The apparatus is described in some detail, and there is a general explanation of the methods used by certain species of insects to produce sounds. A list of the insects studied by the author by making records of their songs is arranged systematically, and in Chapters VI–XIII individual sound records for each species are analysed. In Chapter XIII the author deals in detail with the calculation of wing resonance. Chapter XIV describes the results obtained when the apparatus designed for this research on insects was used in some casual investigations of the songs of a few birds. There is an appendix which comprises further explanation of the performance of the apparatus.

The book is profusely illustrated with photographs of the insects studied, and reproductions of the sound records.

LARVAL SPECIFIC CHARACTERS AND INSTARS OF ENGLISH BOMBIDAE.

By R. A. Cumber, B.Sc.(N.Z.), Ph.D., D.I.C., F.R.E.S.

1. *Larval Specific Characters.*

Fourth instar larval characters of American Bombidae (Bremidae) were described by Ritcher (1933) for nine species of *Bombus* (*Bremus*) and one species of *Psithyrus*. These two genera were separated on the shape of the mandibles. An attempt was made to separate the species of *Bombus* (*Bremus*) on the characters of the mesothoracical spiracles and the pleural sutures. The shape of the spiracles and atrial spines and the width of the peritreme were the main spiracular characters used.

In the present work fourth instar larvae of seven species of *Bombus* and one species of *Psithyrus* have been studied.

Ritcher's division into *Bombus* (*Bremus*) and *Psithyrus* on the respective " mitten-shape " and " falcate-shape " of the distidentes of the fourth instar larvae is verified. In the species studied this distinction is very marked (fig. 1).

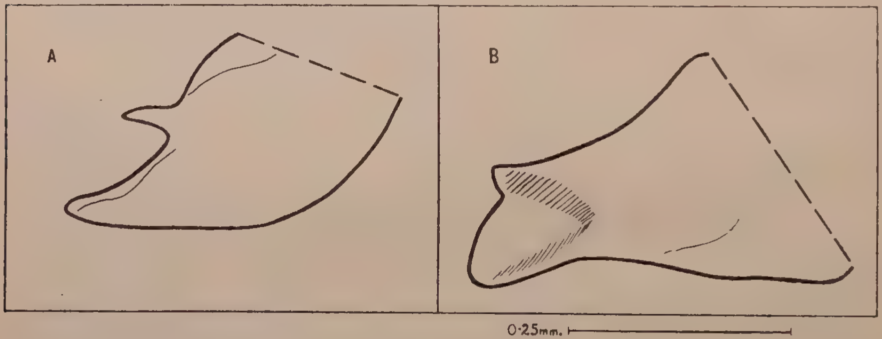

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Fig. 1.—The distal portion of the mandibles of the fourth instar larvae of 1. *Psithyrus rupestris* (Fabr.) and 2. *Bombus agrorum* (Fabr.), to show the " falcate-shape " and " mitten-shape " of the distidentes.

In the seven species of *Bombus* studied here there is some variation in the shape of the mandible, but this is insufficient for specific distinction. The mandibles of *B. hortorum* and *B. agrorum* (" pocket-makers ") tend to be long and slender in comparison with the relatively stumpy condition seen in *B. pratorum* (" pollen-storer ").

In all the species studied branching of the mesothoric atrial spines occurs, and there appears to be considerable individual differences in the extent of branching in the one species. There is a high degree of branching in *Psithyrus* and the " pocket-makers," and a much reduced branching in the " pollen-storers."

PROC. R. ENT. SOC. LOND. (A) 24. PTS. 1–3. (MAR. 1949.)

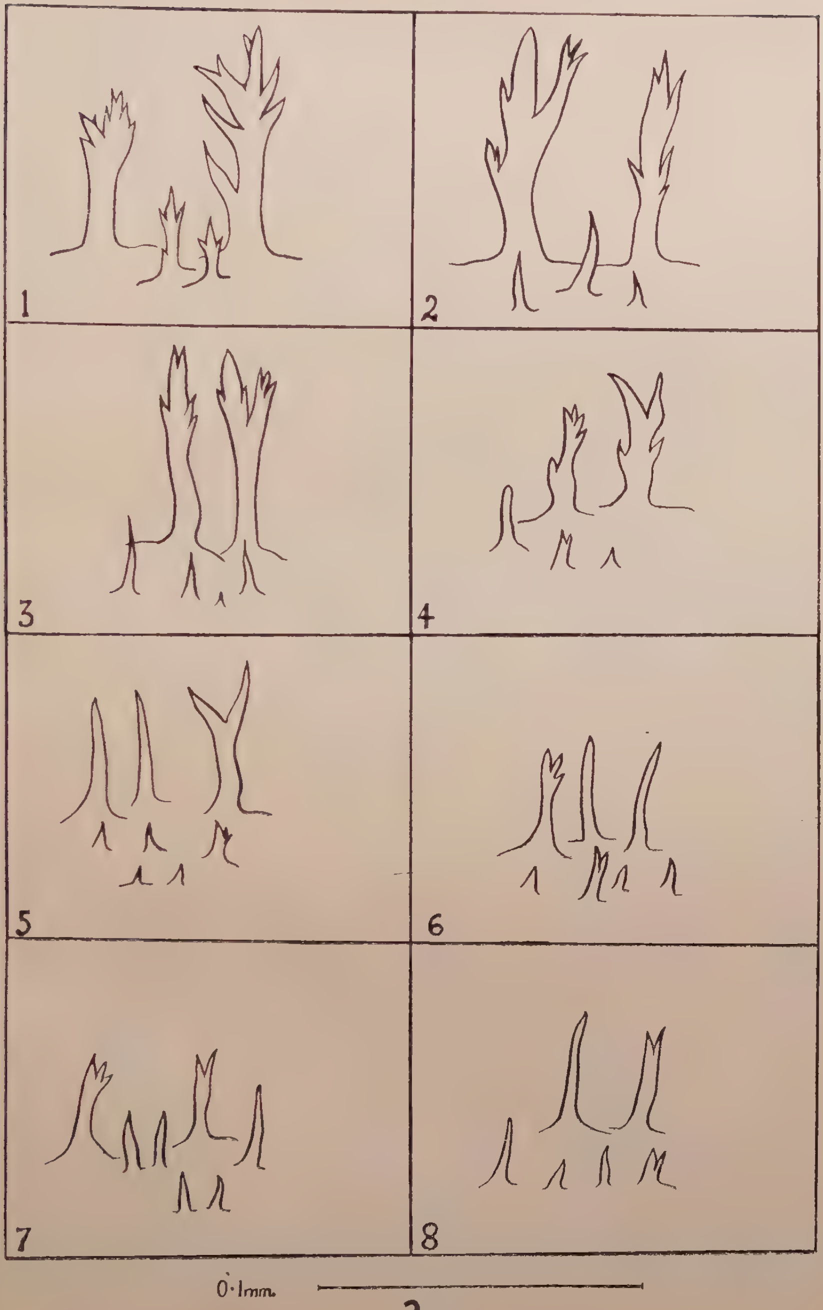

FIG. 2.—Atrial spines from the mesothoracic spiracles of the fourth instar larvae to show the degree of branching. 1. *Psithyrus rupestris* (Fabr.); 2. *Bombus agrorum* (Fabr.); 3. *Bombus hortorum* (L.); 4. *Bombus ruderarius* (Müll.); 5. *Bombus terrestris* (L.); 6. *Bombus lucorum* (L.); 7. *Bombus lapidarius* (L.); 8. *Bombus pratorum* (L.).

The following is a list of the species studied, a series based on the degree and frequency of branching starting with the more complex condition. Numbers five to eight present a fairly uniform series: *P. rupestris*, *B. agrorum*, *B. hortorum*, *B. ruderarius*, *B. terrestris*, *B. lucorum*, *B. lapidarius*, *B. pratorum*.

The "tracheal opening" of Ritcher (central space left by the converging atrial spines) varies in the different species, being small in *P. rupestris* and *B. agrorum*, and relatively large in *B. pratorum*. The apical branching of the atrial processes may be present in the third instar larvae of *B. agrorum*, but not in the earlier instars.

Ritcher made no mention of temporal bands, which are evident in all species studied here.

Atrial spines of the mesothoracic spiracles of the species studied are shown in fig. 2.

2. *Larval Instars.*

Measurements of the Head-capsule.

The width of the head-capsule (from side to side) of larvae was measured in different species to determine the number of instars present. In *B. agrorum*, *B. pratorum* and *B. hortorum* four instars were found. Measurements made with a micrometer eyepiece (1 mm. = 140 units) were grouped for intervals of ten units and their frequency distribution (= F.D.) plotted.

Fig. 3 shows the F.D. of width of head-capsules in larvae from a nest of *B. hortorum* taken on 17.vi.46. Adults in the nest included 2 ♀ (one the original) and 12 ♂. The pupal brood appeared to be all male.

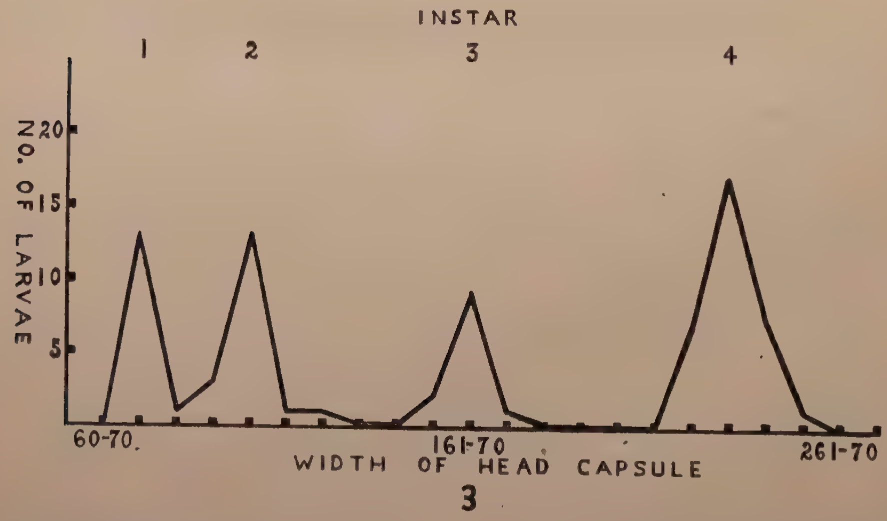

Fig. 3.—Frequency distribution of width of head capsules (1 mm. = 140 units) of larvae from a nest of *Bombus hortorum* (L.).

Fig. 4 shows the F.D. of width of head-capsules in larvae from a nest of *B. agrorum* taken on 28.viii.46. Adults in the nest included 29 ♀ and 15 ♂, and pupae of both sexes were present.

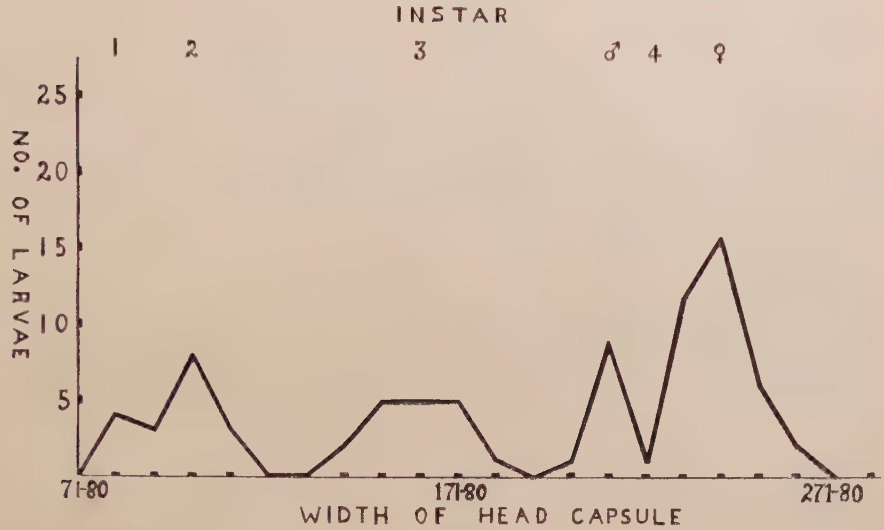

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Fig. 4.—Frequency distribution of width of head capsules (1 mm. = 140 units) of larvae from a nest of *Bombus agrorum* (Fabr.), producing males and queens.

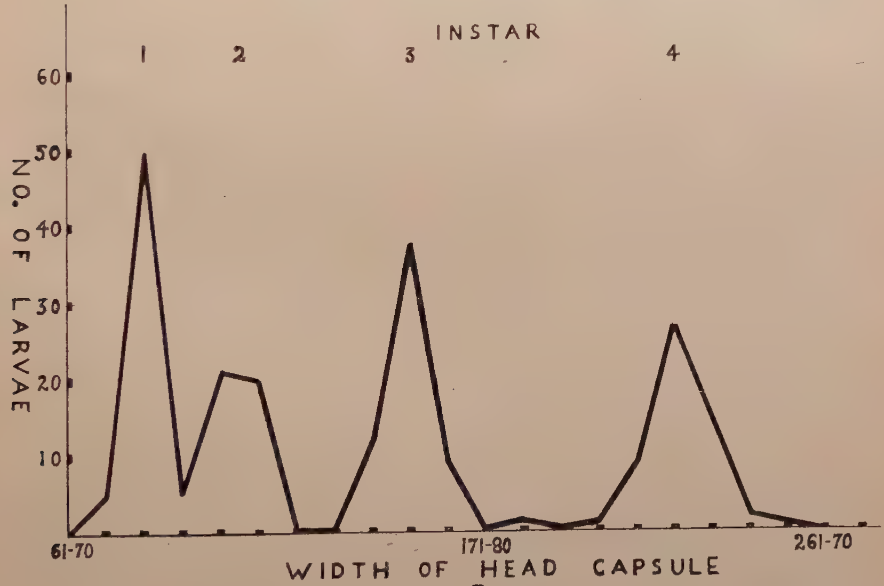

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Fig. 5.—Frequency distribution of width of head capsules (1 mm. = 140 units) of larvae from a nest of *Bombus agrorum* (Fabr.), producing only male brood.

Fig. 5 shows the F.D. of width of head-capsule in larvae from a nest of *B. agrorum* taken on 3.ix.46. Adults in the nest included 38 ♀ and 11 ♂. The brood was wholly male except for a few unemerged queen callows. The larvae here are, then, presumably male, since many workers were laying and the original queen was absent.

The peaks of the first three instars are, generally speaking, well defined. The fourth instar peak, however, has a tendency to be bimodal in fig. 4, where the third instar peak also shows a flattening. It is possible that a mixture of male and female larvae is responsible for this, and a bimodality manifests itself only in the fourth instar. Here the first peak would appear to be that of the male larvae, the second peak that of the queen larvae. This is more or less borne out by the results of measurements of male larvae shown in fig. 5, where it is seen that the fourth instar peak is not bimodal, and that this peak corresponds rather with the male fourth instar peak of fig. 4 than with the female peak.

Table I gives the average width in mm. of head capsules of instars in the species studied. Table II shows the increase between averages of successive instars expressed as a ratio of the earlier instar.

TABLE I.—*Width (mm.) of Larval Head Capsules.*

Species.	Date.	Instar.				Brood.
		1.	2.	3.	4.	
B. pratorum	20.v.46	0·57	0·82	1·11	1·61	☿
B. hortorum	17.vi.46	0·53	0·75	1·18	1·68	♂
B. agrorum	28.viii.46	0·61	0·75	1·18	1·75	♀♂
B. agrorum	3.ix.46	0·61	0·75	1·11	1·61	♂

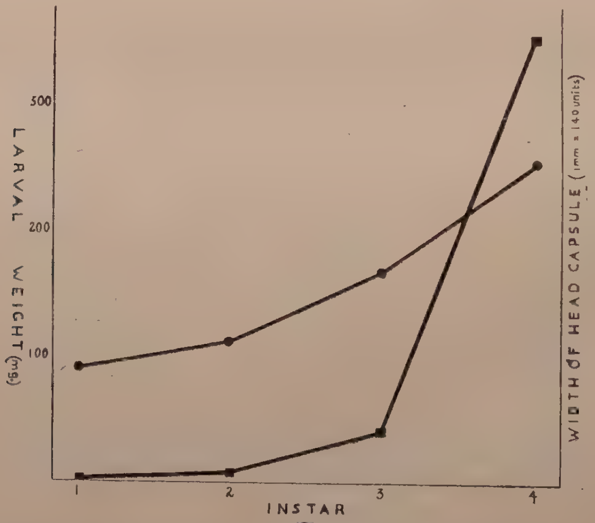

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FIG. 6.—Mean weight of larvae (mg.) and mean width of head capsules (1 mm. = 140 units) for larvae of different instars in a nest of *Bombus agrorum* (Fabr.).

Table II.—*Instar Ratios Based on Width of Larval Head Capsules.*

Species.	Date.	Ratio to preceding instar.		
		2nd instar.	3rd instar.	4th instar.
B. pratorum	20.v.46	1·44	1·35	1·45
B. hortorum	17.vi.46	1·42	1·57	1·42
B. agrorum	28.viii.46	1·23	1·57	1·48
B. agrorum	3.ix.46	1·23	1·48	1·45

Fig. 6 shows the mean weight of larvae of different instars in a nest of *B. agrorum* taken on 28.viii.46, together with the mean width of head capsules for larvae of the different instars.

ACKNOWLEDGMENTS.

The work in compiling this paper has been carried out at the Imperial College of Science and Technology, London. Thanks are due to the staff of the Zoology Department, especially to Dr. O. W. Richards for help throughout the course of the work.

REFERENCE.

Ritcher, P. O., 1933. The external morphology of Larval Bremidae and key to certain species (Hym.). *Ann. ent. Soc. Amer.* **26** : 53–63, 2 pls.

BOOK NOTICE.

The Caterpillars of British Moths, including the Eggs, Chrysalids and Food-plants. Based upon *The Moths of the British Isles*, by Richard South. Compiled and arranged by W. J. Stokoe. Edited, and with special articles by G. H. T. Stovin. Series I, pp. 408, 90 pls. (col.), text illust. Series 2, pp. 381, 51 pls. (col.), text illust. Sm. 8vo. London : F. Warne, 1948. Price 15s. per volume.

These volumes are published in the "Wayside and Woodland Series," and are uniform with the parent volumes, South's *Moths*. The work has been planned and arranged on lines similar to the companion volume dealing with the British Butterflies.

The First Series opens with a chapter on Mendelism in entomology by G. H. T. Stovin, and is followed by the main body of the work, which covers the families Sphingidae to Brephidae.

The Second Series has an introductory chapter on hibernation by G. H. T. Stovin, after which the families Geometridae to Hepialidae are dealt with. Pages 257–360 of this volume deal with the food-plants of the caterpillars of British Moths. The common and scientific names are given in each case, followed by a short description and illustration. This volume concludes with a general index to both series.

The volumes are profusely illustrated with coloured figures, half-tone plates, and a few line drawings.

THE MIGRATORY LOCUST IN ENGLAND IN 1947 AND 1948.

By B. P. Uvarov, C.M.G., D.Sc., F.R.E.S.
(*Anti-Locust Research Centre.*)

Immigration of individuals of *Locusta migratoria* (L.) into England reported in 1946 (Uvarov, 1947) was repeated in 1947, when much more numerous records were collected (*see* Table and Map 1). This increase in records may be due, not to a more extensive immigration, but to better publicity given to requests for information. My sincere thanks are due to all who sent me records and specimens, and to several kind friends, who induced collectors to do so. Amongst such helpers I am particularly grateful to Dr. W. D. Lang, Mr. E. M. Venables and most of all to Captain T. Dannreuther. The names of the collectors are given in the Table.

While in 1946 all recorded immigrants belonged to the French race of *L. migratoria*, originating in the Landes region of south-western France, in 1947 two specimens proved to be of the very distinct Black Sea race. The immigrations of the two races are discussed separately below.

French race (*L. migratoria gallica*).

The French race has now been studied biometrically on extensive material of all phases and recognized as a new subspecies, *L. migratoria gallica* Remaudière (Remaudière, 1947*b*).

As already reported (Uvarov, 1947), the swarming of this subspecies commenced in the Landes and Gironde departments of S.W. France in 1944 and the first swarms were reported to have left the outbreak area in July, 1945. Thanks to the courtesy of Mr. A. E. Ellis, I have been able to examine a gregarious female of the French subspecies, taken by J. and D. Finlay at Honiton, S. Devon, on 3rd July, 1945. Thus, French locusts reached England as soon as swarms of the gregarious phase appeared.

Fuller data are now available with regard to the course of the outbreak and of migration in France in 1946 (Chaboussou *et al.*, 1947 ; Aguilard, Chopard and Remaudière, 1947 ; 1947*a* ; Remaudière, 1947 ; Zolotarevsky, 1946, 1947), when swarms flew from the outbreak area mainly north and north-east, and numerous scattered individuals, and even groups, were recorded over most of France, reaching La Manche department in the north. Therefore, the individuals that reached England in 1946 marked the extreme range of general northward dispersal which must have occurred on a large scale. It is curious, however, that the northernmost French captures refer to September and October and the earliest date is 11th August, when a female was taken in the Seine-et-Oise Department, whereas the first English immigrant was captured in the Isle of Wight on 6th August.

As many as 32 immigrant specimens were reported in 1947 (see Table) ; 25 of them were available for study and 23 were identified as subsp. *gallica*. In 1946 only females were reported, but in 1947 three specimens out of the 23 and in 1948 three out of four were males. Several females were dissected and found to contain fully developed eggs. One female (No. 29), captured at Charmouth, Dorset, on 12th October, reached the Anti-Locust Research Centre alive and laid an egg-pod in captivity, but the eggs failed to hatch. This failure may have been due to the eggs not being fertilized, but it is also known that eggs of the French race require a resting period at a low temperature before they can be incubated (Roubaud, 1947 ; Remaudière, 1948).

An extremely interesting record has come to my knowledge through the kindness of Mr. W. J. Le Quesne who has forwarded me a fifth stage male nymph, typical of ph. *solitaria*, taken by Mr. L. H. Williams at Jersey, Channel Islands, on 31st August, 1948. The exact locality was described as " a heathy area adjoining the north cliffs of the island, an area known locally as Les Platons." There can be no doubt that the nymph was the progeny of a 1947 immigrant, and it provides evidence that eggs of *L. m. gallica* can survive winter in the Channel Islands. However, the nymph had reached its last stage only at the end of August ; it could not have become adult until early September, too late in the season for sexual maturation. According to French observations, *L. m. gallica* becoming adult in June begins to lay eggs only at the end of August. Therefore, the locust appears to have no chance of permanently establishing itself in the Channel Islands.

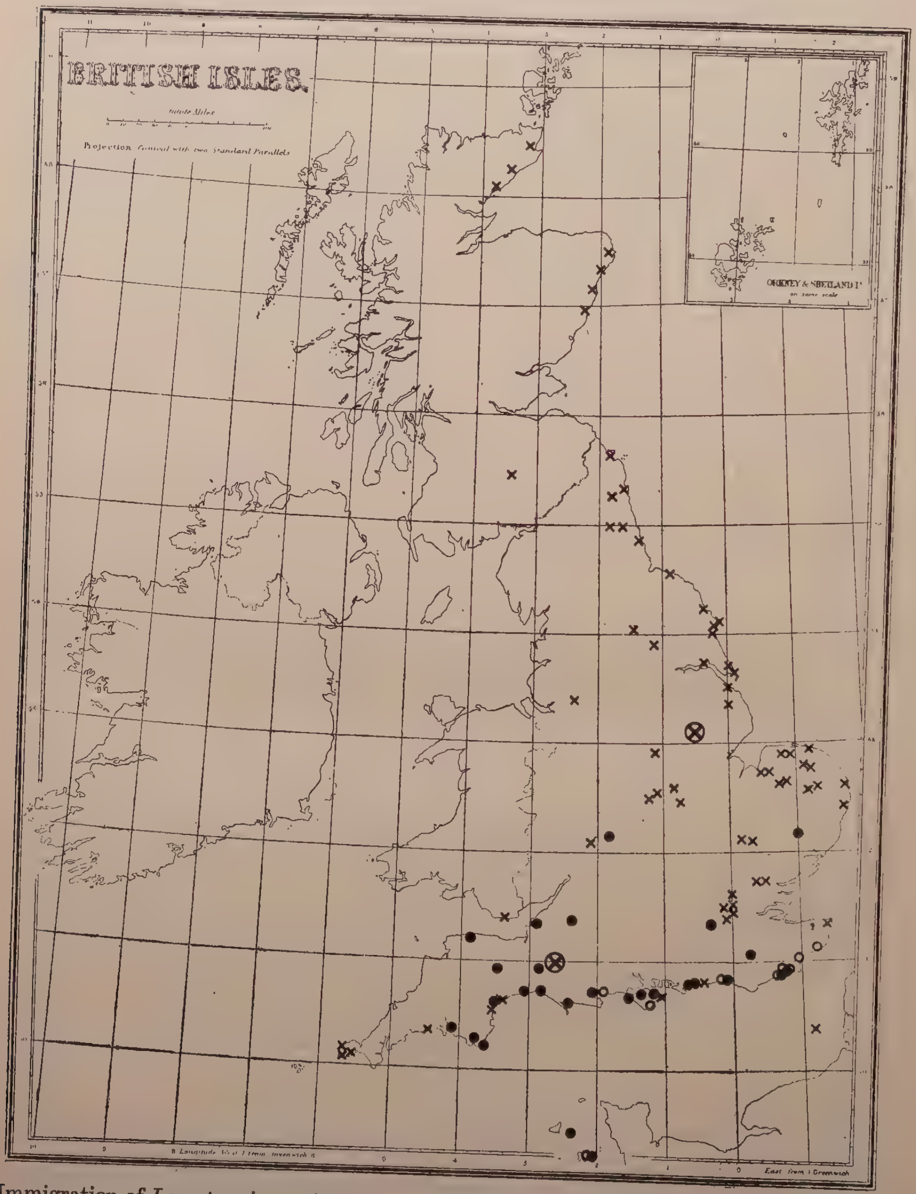
According to M. Remaudière (in a letter to the author) the 1947 swarms were leaving the breeding area in the Landes in July, but no locusts were recorded in England until 5th August. It would appear that the immigration went on throughout August ; of course, later records do not necessarily mean new immigrations although some of the individuals taken as late as October were quite fresh in appearance.

The immigration in 1948 was on a much smaller scale than in the two previous years. Only four definite records have been received, as follows :

Shoreham, Sussex, 29.vii. ♂, *gregaria* (G. E. Hyde).
Bognor Regis, 26.viii. ♀, *solitaria* (J. Reynolds).
Sark, Channel Islands, 1.ix. ♂, *solitaria* (G. Popov).
Ashdown Forest, 6.x. ♂, *solitaria* (J. M. Cullen).

Some difference was observed in the phase composition of the 1946, 1947 and 1948 immigrant populations. In 1946 only individuals of the ph. *gregaria* were recorded, whereas in 1947 five out of 22 immigrants were of the ph. *transiens*. This may mean that wide dispersal of locusts from the outbreak areas in 1946 led to scattered breeding outside these areas, producing ph. *dissocians*. In 1948 individuals of ph. *solitaria* reached the British Isles. Thus we have a definite proof that in the French race all phases are able to migrate for considerable distances. It should be recalled that amongst 44 specimens of *L. migratoria migratoria* (Black Sea race) taken in the British Isles during the period 1846–1939 and studied biometrically, 23 have been referred to ph. *transiens* and 3 to ph. *solitaria* (Waloff, 1940). This suggests that long range flights of all three phases are common to both subspecies.

The dispersal of immigrants after their arrival in England suggests, however, that even the phases *gregaria* and *transiens* of the French race, are less active than locusts of the Black Sea race. As will be seen from the Map, locusts entered England in 1947 on a much wider front than in 1946 and they eventually penetrated fairly far inland, the northernmost record being Stowmarket, Suffolk (No. 30). Their dispersal must have been greatly favoured by the exceptionally hot and dry weather of the 1947 autumn. Two individuals (Nos. 5 and 14) were even taken at light, suggesting migration at night, which is a phenomenon known for swarms of *Locusta* in warmer climates. In spite of these unusually favourable conditions, the dispersal map of subsp. *gallica* is



Immigration of *Locusta migratoria* into the British Isles. Large dots, *L. m. gallica* in 1947; circles, ditto, 1946; large circle, with crosses, *L. m. migratoria* in 1947; small crosses, ditto, 1846 (the last from Waloff, 1940).

Records of *Locusta migratoria* in England in 1947.

E, length of elytron ; F, length of hind femur ; G, ph. *gregaria* ; Tr, ph. *transiens*; Ga, subsp. *gallica* ; M, subsp. *migratoria* ; A.L.R.C., specimen in the Anti-Locust Research Centre.

No.	Date.	Place.	Observer.	Sex.	E.	F.	Phase.	Race.	Notes.
1	5.viii	Seaton, Devon . . .	J. C. Poole	—	—	—	—	—	Not seen.
2	6.viii	Colwell Bay, I. of Wight .	C. A. Bartlett	—	—	—	—	—	
3	8.viii	Heybrook Bay, Plymouth .	O. G. Watkins	♂	38	18·5	G.	Ga.	Examined
4	11.viii	Charmouth, Dorset . .	W. D. Lang	♀	45	25	Tr.	Ga.	A.L.R.C.
5	11.viii	Start Point Lighthouse, S. Devon	G. W. Phillips	♂	43	23	Tr.	Ga.	A.L.R.C.
6	12.viii	Mayfield, Sussex . .	H. J. Knight	♀	46	23	G.	Ga.	A.L.R.C.
7	14.viii	Bembridge, I. of Wight .	G. Frampton	—	—	—	—	—	Not seen.
8	14.viii	Tiverton, Devon . .	R. Brown	♀	43	—	G.	Ga.	Examined
9	15.viii	Hutton, nr. Weston-super-Mare	I. A. Stephenson	♀	47	26	Tr.	Ga.	A.L.R.C.
10	18.viii	Kingsbridge, S. Devon .	J. Edwards	♀	42	23	Tr.	Ga.	A.L.R.C.
11	18.viii	Bath, Somerset . . .	W. M. Gibb	—	—	—	—	—	Not seen
12	18.viii	Sark, Channel Islands . .	F. Zeuner	—	—	—	—	—	Not seen
13	viii	Weymouth . . .	A. Cole	♀	48	23·5	G.	Ga.	A.L.R.C.
14	20.viii	Ilminster, Somerset . .	H. W. Hutchings	♀	46	23	G.	Ga.	A.L.R.C.
15	21.viii	Fairlight, Hastings, Sussex .	A. D. Wilkinson	♀	43	22	G.	Ga.	A.L.R.C.
16	22.viii	Start Point Lighthouse, S. Devon	G. W. Phillips	♀	45	24	Tr.	Ga.	A.L.R.C.
17	viii	Ilchester, Somerset . .	C. J. Vickery	♀	57	27	G.	M.	A.L.R.C.
18	viii	Portelet, Jersey, Channel Islands	R. J. Tanner	—	—	—	—	—	Not seen
19	4.ix	Decoy Heath, Wareham, Dorset	A. E. Ellis	♀	47	23	G.	Ga.	Examined
20	5.ix	Newtown, I. of Wight .	A. McClelland	♀	44	—	G.	Ga.	Examined
21	12.ix	Welbourn, Lincolnshire .	F. T. Baker	♀	58	27	G.	M.	A.L.R.C.
22	17.ix	Bognor Regis . . .	A. Hazel	♀	46	23	G.	Ga.	A.L.R.C.
23	22.ix	Starcross, Devon . .	H. King	♀	—	—	G.	Ga.	A.L.R.C.
24	22.ix	Leatherhead, Surrey . .	J. E. S. Dallas	♀	50	26	G.	Ga.	A.L.R.C.
25	24.ix	Kemptown, Brighton . .	H. Blackiston	—	—	—	—	—	Not seen
26	ix	North Devon Coast . .	B. L. Boyle	♂	42	22	G.	Ga.	A.L.R.C.
27	1.x	Winchelsea, Sussex . .	M. J. David	♀	48	24	G.	Ga.	A.L.R.C.
28	4.x	Bidford, Warwickshire .	C. Holder	♀	48	24	G.	Ga.	A.L.R.C.
29	12.x	Charmouth, Dorset . .	W. D. Lang	♀	—	—	G.	Ga.	Alive
30	14.x	Stowmarket, Suffolk . .	M. Dawson	♀	?	26	G.	Ga.	A.L.R.C.
31	x	Felpham, Bognor, Sussex .	S. M. Shephard	♀	49	24	G.	Ga.	Examined
32	x	Dawlish, S. Devon . .	J. Whetman	♀	44	?	G.	Ga.	A.L.R.C.

strikingly different from the similar maps for subsp. *migratoria*, immigrants of which usually reach England along the East Coast and disperse very widely, reaching Scotland and even the Hebrides (Map).

Black Sea race (*L. migratoria migratoria*).

Two females, No. 17, taken in August at Ilchester, Somerset, and No. 21 captured on 12th September at Welbourn, Lincolnshire, proved to belong to the Black Sea race, *Locusta migratoria migratoria* (L.), which was the only race of the species known to immigrate into the British Isles before 1945 (Waloff, 1940). They were both of the ph. *gregaria*, suggesting that this race is swarming in its outbreak areas at present. No information on this point could be obtained, except some radio reports in the early summer of 1947 announcing that large scale anti-locust operations, involving the use of aircraft, were planned in the Danube delta. As will be seen from the map, the two 1947 records are within the area normally reached by the Black Sea immigrants.

Supposed immigration of locust parasites.

The late Mr. C. J. Wainwright drew my attention to the fact that *Stomorrhina lunata* (F.), a Muscid parasite of locust eggs, which had only been very occasionally recorded in England (Wainwright, 1944), was, in 1947, taken on two occasions: at Mudeford near Christchurch (2 specimens) and at Bristol (31 specimens on a clump of golden rod (*Assis-Fonseca*, 1947)). Mr. Wainwright suspected that the flies were immigrants and suggested that their arrival in this country in unusual numbers in 1947 may have had some connection with the immigration of locusts. This interesting theory, however, appears difficult to support. The adult female of *S. lunata* is known to wait near a locust female ready to oviposit, and the parasite lays its eggs into the cavity dug by the locust as soon as the latter withdraws its abdomen (Jannone, 1947). Larvae of the parasite make their way down to the locust eggs and the whole metamorphosis, until the emergence of the adult, occurs underground. There is no evidence that the flies ever accompany, or follow, flying locusts. It is unlikely, therefore, that the parasites could reach England actually flying with locusts.

Another possibility is that the flies may have been enabled by meteorological conditions to migrate from the same original areas as the locusts and at the same time but independently. I am informed by M. Remaudière, however, that *S. lunata* was a common egg-parasite in the locust outbreak area in September, 1945, and in March, 1946 (Remaudière, 1947*a*), but had disappeared from there by the autumn of 1946; in 1947, he saw only a single adult, but no larvae or pupae were found in locust egg-beds. Therefore, in 1947 one could hardly expect an unusual migration of the flies originating in the locust outbreak area. A much more probable explanation is that the flies became rather more abundant than normally in France in 1945–47, breeding on scattered locust populations, and numbers of adult flies were able to reach England from unknown areas of the continent. Alternatively, it is not impossible that *S. lunata* can breed on eggs of some British grasshoppers, and that its numbers occasionally increase owing to some favourable conditions. Of course, these are also only theories, and I am grateful to Mr. Wainwright for drawing my attention to the facts, which certainly suggest the need for further observations.

Expected immigration in 1949.

No data are available at the time of writing as to the extent of the infestation in France in autumn, 1948, but an immigration of subsp. *gallica* into the British Isles may occur again in 1949, from July onwards, if only on a small scale. The subsp. *migratoria* may also appear.

Observers and collectors of immigrant locusts are requested to communicate with the Anti-Locust Research Centre, British Museum (Natural History), London, S.W.7.

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NOTES ON THE NEST-BUILDING OF A SOLITARY WASP, *EUMENES LATREILLI PETIOLARIS* SCHULZ, 1903, AT JACQUINOT BAY, NEW BRITAIN (HYMENOPTERA).

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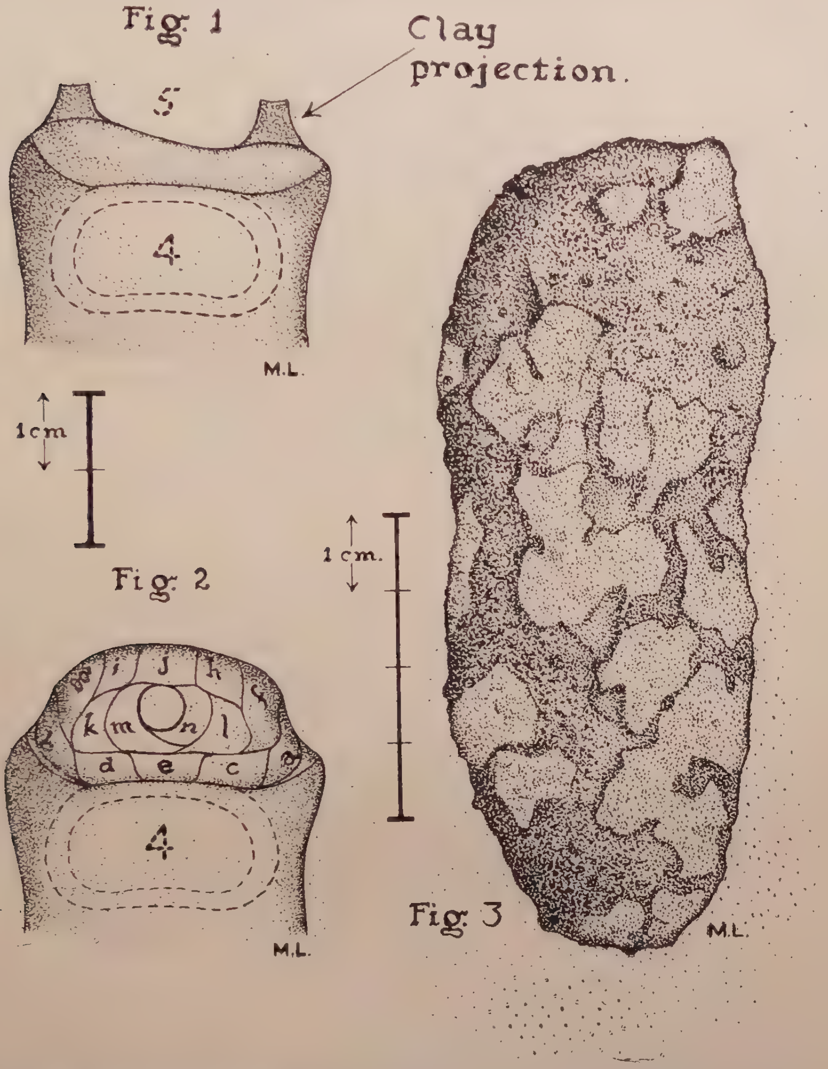
A female of *Eumenes latreilli petiolaris* Schulz commenced building a clay nest on the malthoid wall of my laboratory at Jacquinot Bay, on the morning of 5th October, 1945. First of all a concave shelf of clay some 2·5 cm. long was built out from the wall to a distance of 5 mm., one half-metre from the ground. The wasp brought a ball of mud to the building site every two or three minutes, and averaged about half a minute in moulding the load into place in the nest before departing again.

Following the route taken by the insect through a narrow belt of jungle adjacent to the laboratory, I found that the mud balls were rolled at a patch of damp clay near the edge of a drying rain pool just over a hundred yards from the building site. After first taking up a little water from the pool, the wasp began to manipulate the clay by means of its mandibles and first pair of legs. The resultant ball averaged some 6 mm. in diameter.

So as to have a close view of the building operations without unduly disturbing the insect, a circular hole was cut in the malthoid wall to one side of the nest. By jamming a four-inch petri dish into this hole and mounting a mirror focussed on to the nest just outside, I was able to make observations from within the laboratory. On returning to its nest after these alterations had been made, the wasp displayed obvious uneasiness. It hovered in front of the mirror and petri dish window for a short time, then dropped the mud ball to the ground and flew away without attempting to settle. It returned, however, after an absence of almost two hours, and recommenced its building activities.

During flight the *Eumenes* held the ball of mud between mandibles and thorax only. The front pair of legs were only brought into play after it had settled on the nest and moved to the place where the clay was to be spread. Then, while the fore legs lightly grasped the mud ball at the rear, the mandibles were moved back and forth paring thin layers from the ball and plastering these onto the nest. When all the mud had been spread out, backward trowelling movements of the mandibles smoothed over the surface of the newly-completed section. The wasp would now briefly stroke another part of the surface of the nest with its antennae before flying away. It would alight and begin to build at this place on returning with a further load of mud. Oviposition followed the completion of each cell, mass provisioning with from two to four paralyzed coleopterous larvae then taking place. After sealing the remaining aperture with a final ball of mud, the wasp would plaster more mud on to the nest until the newly-completed cell and the ones below appeared as a single uniform mound.

Work was carried on only during periods of bright sunshine, the building of a single cell taking about two hours. Once during dull weather the *Eumenes* remained absent from the building site for twenty-four hours.



FIGS. 1–3.—(1) The top of the nest of *E. l. petiolaris* when building operations ceased for the day on 9th October. (Semi-diagrammatic.) (2) The top of the nest of *E. l. petiolaris* before the sealing and camouflaging of cell 5, showing the distribution of the loads of mud used in building this cell. (Semi-diagrammatic.) (3) The completed nest of *E. l. petiolaris*.

The first cell was completed on the morning of 5th October. Five more were added in a vertical series on top of this one, on the afternoons of the 7th and the four days following. On the 10th the whole process of building the fifth cell was observed and timed (figs. 1 and 2). The top of the nest appeared as shown in fig. 1 when the *Eumenes* ceased its building operations at 3.35 p.m. on 9th October. In this figure the positions of the inner and outer walls of cell " 4 " are indicated by broken lines. It will be seen that the thick plastering of mud around this cell quite obscured its individual outline. The top surface of the nest was left as a thin, concave shell, and the final act of construction for this day was the addition of two clay projections, each built from a single ball of mud, against the hut wall on either side of the top rear of the nest.

At 12.15 p.m. on 10th October the *Eumenes* reappeared and flew about in the vicinity of the nest. It did not settle and soon flew off again, and did not return until it brought back a ball of mud at 12.40 p.m. This ball was built out as a wall originating against the clay projection at the top right-hand side of the nest, and curving out over the top surface (fig. 2, " a "). Going over to the opposite side of the nest the insect now touched the clay projection there with its antennae. It flew off after spending 45 seconds on the nest, returning three minutes later with a fresh mud ball. A similar section of wall to the one already built was now constructed on the left-hand side (fig. 2, " b "), after which the *Eumenes* again moved to the opposite side of the nest and felt about the edge of section " a " with its antennae before departing. Working thus alternately from side to side of the cell, the insect had added sections " c "–" g " by 1.10 p.m., averaging 40 seconds in actual building time on each section. Three more balls of mud were used for the roof of the cell (fig. 2, " h "–" j "), the *Eumenes* working on this section in a head-downwards position. The femora of the front pair of legs steadied the mud ball and slowly fed it outwards and downwards to the mandibles, the head being bent under inside the cell cavity. Together with the tibiae the femora were then used in smoothing movements on the outside of the roof section under construction, while the mandibles fulfilled a similar function on the inside. Meanwhile, the antennae maintained a continual fluttering contact with the inner surface of the roof of the cell. The wasp spent an average of a minute and a half in building each section of roof, that is to say something over twice the time taken for each of the preceding sections. After completing the roof of the cell at 1.24 p.m., the insect remained absent until 1.40, when it reappeared without a load of mud and did not settle on the nest. At 1.43 p.m. work was begun on the left-hand side of the front wall of the cell, the *Eumenes* again adopting a head-downwards working position. The adding of this section (fig. 2, " k ") took 1 min. 18 sec. Before leaving the nest the wasp stroked the right-hand edge of the narrowing opening with its antennae. On returning three minutes later with a fresh load of mud it built section " l " in 1 min. 12 sec. The final sections " m " and " n " were constructed in 1 min. 19 sec. and 1 min. 30 sec. respectively, after which the wasp spent almost two minutes in moving slowly around the opening, first clockwise then anti-clockwise, smoothing the edges with its mandibles. On the completion of this task the aperture was almost perfectly circular, and 6 mm. in diameter.

After an absence of only one minute the *Eumenes* returned and began to oviposit, inserting the abdomen up to its broadest segment into the cell. The wasp flew off immediately after oviposition, which began at 2.00 p.m. and ended 1 min. 20 sec. later. A hole was now pierced through the malthoid wall at the back of cell " 5 " and the gleaming white, sausage-shaped egg could be seen suspended by a short filament from the centre of the roof. Nine minutes later the wasp returned, landing at the cell aperture and feeling about the edges with its antennae. It then moved slowly down the left-hand side of the nest and up the right-hand side, feeling the surface with its antennae all the way. After a stay of two minutes it flew off, and remained absent for fifteen minutes. On its return it landed at the aperture of cell "5" once more, and spent just over a minute feeling about the edges and over the adjacent parts of the surface of the nest with its antennae before departing again.

At 2.44 p.m., fifteen minutes after its last visit to the nest, the *Eumenes* returned with a paralyzed carabid larva dangling beneath its head and thorax. The inch-long larva was grasped by the head, and steadied between the wasp's mandibles and front legs during flight. It was now placed within the cell in close contact with the front wall, this act taking just over a minute to accomplish. Six minutes later, and again two minutes after that, very brief visits were made to the nest. On both occasions the *Eumenes* flew straight to the aperture and touched the edges with its antennae, departing immediately afterwards. At 3 p.m. a second beetle larva was packed into the cell in the space behind the first one. The wasp left at 3·1, returning three minutes later with a mud ball which it plugged into the aperture and trowelled into continuity with the outer surface of the cell. In the next hour sixteen balls of mud were plastered at random over cell "5." The nest, when left for the last time that day at 4.5 p.m., had much the same appearance as on the previous evening (fig. 1).

Cell "6," the last one to be built, was constructed in the same fashion and in approximately the same time as that just described above, on the afternoon of 11th October. In this instance, when oviposition took place the egg was merely dropped on to the floor of the cell instead of being suspended from the roof. Although several further visits to the nest were made during the late afternoon, no immobilized larvae were brought to the new cell. The final visit for the day was made at 4.50 p.m., the *Eumenes* merely hovering in front of the nest without settling, and departing without sealing up the aperture.

At 11.10 a.m. on 12th October the wasp again appeared at its nest with a ball of mud. This was used in partly sealing the aperture of cell "6," the work being completed with a second ball. The final cell was thus sealed up without being provisioned.

Further visits were made at 12 a.m. and 12.9 p.m., the *Eumenes* spending about ten seconds moving over the nest and feeling the surface with its antennae on each occasion. The same behaviour was displayed during a fourteen-second visit made at 12.33 p.m. Six minutes later the wasp reappeared, landed on the plug of cell "6," and left immediately. From 12.43 p.m. onwards the insect made visits averaging 30 seconds in duration every two or three minutes. Mud-balls, the clay being brought from a different locality from that used previously, and of a markedly lighter colour, were smeared irregularly over the surface of the nest (fig. 3). The task was finished by 2.00 p.m., by which time the completed structure was perfectly camouflaged by its irregular outline and mottled appearance, giving no suggestion of an insect nest.

Through the hole pierced in the back wall of cell "5" it was seen that a larva had hatched out, at 3.00 p.m. on the 12th. This larva was dead at the end of a further two days, perhaps because of my interference with the cell. The egg laid on the floor of cell "6" on the 12th never hatched. On 23rd

October, shortly before leaving New Britain, I opened cells "2," "3" and "4" from the back. The larva in cell "4" had apparently been dead for some time, but cells "2" and "3," completed on 7th and 8th October, were silk-lined and contained pupae. These pupae were outwardly similar, except for the fact that the developing eyes of the younger one were deep pink in colour whereas those of the other were black. Both specimens were removed from the nest and preserved. The cast larval skins, faecal pellets, and the more chitinous parts of the carabid grubs devoured by the developing eumenid larvae, were found in a lower corner of each cell between the silken lining and the clay wall.

Cell "1" was not interfered with, but the nest and the malthoid to which it was attached were cut from the wall and packed in a tin in which air-holes were pierced. Shortly afterwards I left for New Zealand. On 6th November, when on board ship two days out from Wellington, the tin containing the nest was opened. The back of cell "1" was cut away, revealing an actively moving female *Eumenes*. This cell had been sealed up on 5th October, the insect within thus having taken 32 days to reach full development.

Roth (1885) and Donnell (1944) describe the nest-building and development of *Eumenes latreilli* Saussure in Queensland and Gippsland. On finding that there are subspecies of this wasp in the islands north of Australia, Schulz (1903) accords the mainland species subspecific rank as *Eumenes latreilli latreilli*. The last-named author also describes *E. l. petiolaris* from New Guinea and adjacent islands. From the observations of Roth and Donnell, it seems that *E. l. latreilli* resembles *E. l. petiolaris* in the type of building site chosen and the method of rolling the mud balls and plastering these on to the nest. The two subspecies differ in that while the latter builds a vertical nest, the former builds a horizontal one with a lower row of seven or eight cells and an upper row of three or four more (Roth, 1885). Fifty-one days were required for complete development by the *E. l. latreilli* observed by Roth, as opposed to the 32 days noted for *E. l. petiolaris*. A further interesting point of difference between these insects is that while the cells of the former are stocked with paralyzed larvae of Lepidoptera ("a common green caterpillar which infested all our vegetables"—Roth, 1885), those of the latter are provisioned with coleopterous larvae (CARABIDAE). According to the literature "caterpillars" are the customary prey of *Eumenes*. There is a possibility that some observers may have loosely applied this term to larvae of insects other than Lepidoptera.

Differences in behaviour between closely related eumenid wasps may have definite classificatory value. Ducke (1914) holds that there is no significant progressive specialization in body structure among the VESPIDAE, but that there is a gradual progressive development of social qualities. This author derives the five sub-families of social wasps from the EUMENINAE. All members of this sub-family lay the egg in some form of nest before carrying out provisioning with paralyzed insect larvae. The nest may be an already-existing cavity merely plugged up with clay, a cell excavated in the ground, or a clay structure built in an exposed position (Wheeler, 1928). Members of the genus *Eumenes* build nests of the latter kind. These may take the form of oval or gourd-shaped cells, built singly or in groups. After being provisioned and sealed up, the cells may be smeared over with clay as camouflage, the form of the finished nest varying with the species concerned. In view of this variation, more information as to the differences in behaviour between *E. l. latreilli* and *E. l. petiolaris* is much to be desired, particularly as to whether or not the horizontal as opposed to vertical alignment of the nest constitutes a subspecific character.

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[1] Not seen in original. See Wheeler (1928 : 68).

A MIGRATION OF *PAPILIO BROWNI* (LEPIDOPTERA) OBSERVED AT JACQUINOT BAY, NEW BRITAIN.

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Large flights of the swallowtail butterfly, *Papilio browni* Godman and Salvin, 1879, were observed crossing Palmalmal coconut plantation at Jacquinot Bay on the mornings of 18th and 19th October, 1945. On both occasions the insects headed due north across the plantation and followed the same flight path. There was no indication of any return movement later in the day. The migrating stream, composed of both males and females, was never more than thirty yards wide, the butterflies flying at heights ranging from about four to forty feet from the ground. Flight was extremely rapid and erratic, making it a difficult matter to net specimens despite the heavy concentration present.

From time to time other species appeared for brief periods to be taking part in the migration, but these always left the stream before flying more than a few yards. *Terias hecabe* Linnaeus, 1758, a common butterfly in open country at Jacquinot Bay, was notable in this connection. *Papilio browni* was not observed in the open plantation at any other time than during the migration, but was normally quite common in jungle and rain forest.

Other duties kept me from attempting to count the numbers of *P. browni* taking part in the mass movements on 18th and 19th October. On the morning of the 20th I went to the place where the insects had emerged from the jungle on the two preceding days. In the event of the movement again taking place, I planned to make an estimate of the numbers of butterflies passing each minute, as they flew across a patch of clear sky to the side of two palm trunks aligned in front of me parallel to the direction of flight. The first Papilionid flew out from the jungle a few seconds after 10 a.m. From then onwards until the movement ceased at midday counts of the numbers observed each minute were made at 15-second intervals. Fig. 1 shows the results of this series of observations, the total count for each minute being represented by a black dot. The solid line is merely intended to show the general trend of the density of the flight, and has no statistical significance. It should be noted that entries of above 150 insects per minute are estimates correct to about plus or minus fifteen.

Over the two-hour period of the migratory flight 6838 *P. browni* were recorded as passing the observation point. As the 15-second rest interval between counts occupied one-fifth of the migration period the total number of butterflies involved could not have been far short of 8000. Thus an average of about 66 insects per minute flew past on the 30-yard front. Williams (1942) suggests a classification of density of migration, on the basis of the numbers passing across a front of a given width in a given time. The scale of densities runs from " I " (extremely thin, one to two insects per 25-yard front per 5-minute period—" only noticeable by careful watch by an expert ") to " VII " (" snowstorm," 1160 to 2500 or more insects per 25-yard front per minute—" interferes with pedestrians," etc.). On the basis of this classification, the Jacquinot Bay migration as observed on 20th October had an average density of " V " (thick, 54 to 250 insects per 25-yard front per minute—" obvious to the general public ").

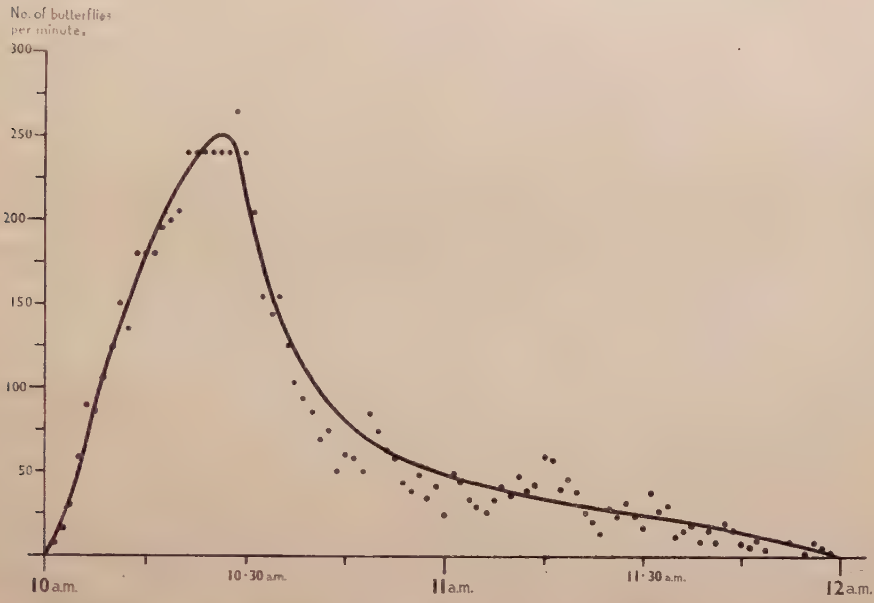

Fig. 1.—Record of the migration of *Papilio browni* at Jacquinot Bay, New Britain, 20th October, 1945.

The initial increase in numbers was most rapid, as may be seen from Fig. 1. When the peak was reached at 10.30 a.m., " 250–280 " butterflies flew past in a single minute. Just over half of the estimated total was recorded in the first half-hour of the flight, the insects flying as a more or less steady stream. There was an abrupt decline in the numbers flying past over the next fifteen minutes, followed by a more gradual decline for an hour and a quarter (Fig. 1). Throughout this period the butterflies showed a tendency to fly as small parties separated by short intervals. In the last half-hour some individuals were seen to turn back in the direction from which they had come, or to circle. This apparent uncertainty of direction increased as the numbers of participants in the movement decreased, until the flight ceased altogether at midday.

Throughout the morning the shade temperature averaged 28·5° C. On the whole the weather was sunny, as indeed it was over the whole period of the migration. An initial flat calm was followed by S.S.W. to S. winds of an average velocity of 3½ miles per hour Despite these changes in wind conditions the butterflies maintained their due north course.

On each of the following two days the mass movement continued during the later part of the morning, the average density of insects involved remaining about the same. Noticeable daily flights were still taking place when I left New Britain on 26th October, but the migration density had lessened appreciably. Preparations for departure prevented my making any further detailed observations. A friend who remained behind at Jacquinot Bay states that flights of *P. browni* persisted until 29th October. For its first five days the migration had an average density of " V " on Williams's scale, and thereafter presumably decreased to " III " (thin, three to eleven insects per 25-yard front per minute —" should be obvious to any observant field naturalist "). It may of course have tapered off over a longer period than the recorded twelve days, the density having become so reduced as to escape the notice of an untrained observer.

There is no previous published record of a migration of *P. browni*. Ormiston, however, observed " great numbers " of *Papilio agamemnon menides*, a closely related species, migrating in a southerly direction during November at Patipola, Ceylon (Williams, 1927). It will be remembered that the migration of *P. browni* took place in the latter part of October, in a northerly direction. Although the migration of the two species took place in opposite directions, it is of interest to note that in both cases the time of flight coincided with the latter part of the rains—those due to the south-east Trades in the case of *P. browni* moving north from Jacquinot Bay, and to the north-east Monsoon in that of *P. agamemnon menides* moving south from Patipola.

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1949

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